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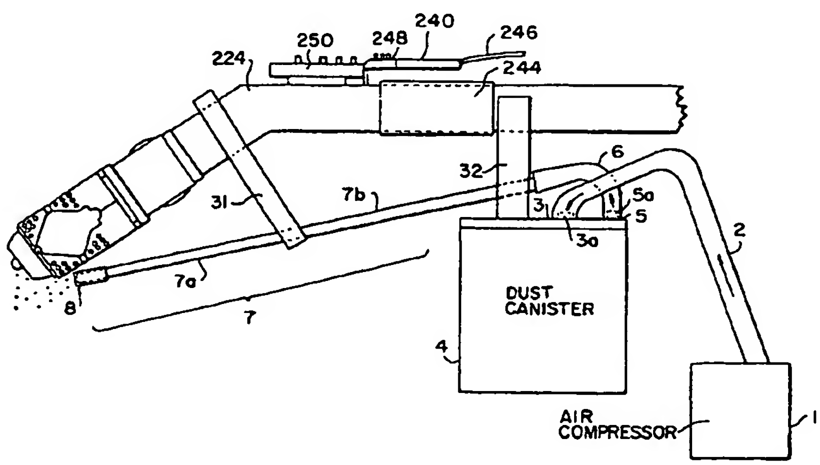

(57) Abstract

A portable explosive detection system with enhanced sensitivity for non-volatile plastic explosives, including a portable dusting device, a vacuum sampling apparatus, an adsorption/desorption apparatus (410) and an analysis subsystem (460). The detection system operates by collecting samples from suspect surfaces with a vacuum. The vacuum head (28) is useable in two modes. The first mode is with a perforated cover (26) opened so that a rotating brush (14) protruding from the vacuum head (28) is exposed; the second mode is where the perforated cover (26) is closed so that the rotating brush (14) is not exposed. The two modes allow the vacuum head (28) to be used on different types of surfaces and clothing, safely. The system collects both vapors and particles left previously on a suspect surface. With the aid of the dusting device mentioned above, wood dust particles (10) are applied to the surface being sprayed thereon before the collect of samples begins. The wood dust (1) has an affinity for the particulates sought which enhances the amount of particles collected thus enhancing the sensitivity of the system. Samples collected are adsorbed on a special substrate (426) and then flash heated to vaporize and desorb all of the materials thereon at once. An analyzer (460) then tests the vapors for the presence of signature molecules.

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METHOD AND APPARATUS FOR ENHANCED DETECTION OF EXPLOSIVES

BACKGROUND OF THE INVENTION

1. Field of the Invention.

This invention relates to improvements in the field of detecting explosives by analysis of vapor or vaporized particles. Specifically, the present invention relates to dusting method and apparatus used with a detection device which greatly enhances the ability of the detection device to detect plastic explosives.

2. Discussion of Prior Art.

With an increase in the frequency of terrorist activities involving transportation and use of explosive devices and compounds, the government and private sectors have been hard at work developing better means of detecting such explosives in order to increase the safety of public transportation such as planes, busses, etc. Technology has afforded use of several detection devices and methods using different devices. The category of devices are two: non-vapor detection and vapor detection.

Non-vapor detection is only useable where living organisms are not exposed. This is because non-vapor detection uses such processes as X-ray detection, gamma-ray detection, neutron activation detection and nuclear magnetic resonance detection. All of these methods are dangerous to living tissue and thus are limited to use on such things as baggage and inanimate containers.

Vapor detection methods on the other hand are useful in detecting explosives even on living subjects because no threat is posed to living organisms by the vapor detection apparatus and method. Vapor detection methods include electron capture detection, gas chromatography detection, mass spectroscopy detection,

bio-sensor detection and laser photocaustic detection. Each of these can be used to detect vapor phase particles of the explosives itself from the residue left behind on hands or clothes of those who hav handled the substances.

With the advent of plastic explosive materials such as Semtex, C4 and DM-12 even more sensitive detection devices and methods have become necessary. Plastic explosive materials have very low vapor pressures which means that very few vapors are released from the substance. Where this is the case, it follows that the substance is very difficult to detect.

Fortunately, for those attempting to detect the existence of plastic explosives in suspect areas, plastic explosives are sticky. Particles of the material are transferred to the hands and clothing and surfaces by merely coming in contact with the same. The residue that remains after such contact can be vacuumed-up in particle form and collected on a specially prepared surface inside a vacuum collection device.

Subsequent to collection of the particular matter, the same is heat-vaporized in a smaller environment so as to concentrate the substance being measured. The collection/concentration step may then optionally be repeated in an even smaller environment so even extremely small amounts of plastic explosive particles on a suspect surface can be detected effectively.

Still however, in the interest of mass safety it is always desirable to detect even smaller amounts of particles on a suspect surface. To this end the inventors of the subject matter of this application have developed a method and apparatus to enhance the sensitivity of prior art detection devices.

SUMMARY OF THE INVENTION

The present invention is directed to increasing the reliability and sensitivity of explosive material detection devices. The method and apparatus comprise spraying dust particles over a surface suspected of having been contaminated with compounds associated with plastic explosive materials. The dust particles are then removed by a vacuum collection device and analyzed.

The present inventors have discovered that by spraying the dust particles on to the suspect surface before vacuum collection, the results of the detection analysis are significantly improved. To this end the present inventors have also built a spray device adapted to easily and effectively disperse the desired dust particles onto a suspect surface such as an individual or baggage in an airport or at a crime scene or in a suspect's abode or workplace. The dusting apparatus has been designed to be used with explosive detection screening systems of the type comprising a sampling means, sample collection and concentration means, analysis means and data processing systems which provide the operator with positive or negative feedback.

The dust spraying device comprises a dust canister with inlet and outlet orifices through which a compressed gas, which acts as a propulsion medium for dust from the dust canister, is pumped. The pressurized gas is pumped via a compressor and a gas supply conduit into the dust canister and forces dust particles to be fluidized and ejected from the dust canister into the application tube whereafter the fluidized dust particles being mixed with the pressurized gas are sprayed onto a suspect surface through a discharge outlet at the end of the application tube. The pressurized gas could also be from a gas canister.

The present invention, in a climate of growing terrorist activities, enables an even higher degree of detection accuracy without sacrificing the ability to make detection screening a speedy process.

BRIEF DESCRIPTION OF THE DRAWINGS

The following described drawing figures are for illustrative purposes only and should not be construed as limiting the particular construction of the apparatus.

Figure 1 is a side view of a hand-held vacuum wand and dusting device constructed in accordance with the teachings of the present invention.

Figure 2 is a plan or top view of a hand-held vacuum wand and dusting device constructed in accordance with the teachings of the present invention.

Figure 3 is a side view of the vacuum head with perforated cover fully open and illustrating configuration of top section and side section of perforated cover.

Figure 3a is a top view of the vacuum head.

Figure 4a is an illustration of the vacuum head used with the present invention with a perforated cover fully open.

Figure 4b is an illustration of the vacuum head used with the present invention with a perforated cover but partly open.

Figure 4c is an illustration of the vacuum head used with the present invention with a perforated cover but fully closed.

Figure 5 is a cross-sectional view of the vacuum head.

Figure 6 is an enlarged view of the splined shaft of the vacuum head.

Figure 7 is a diagrammatic representation of the automated baggage/parcel sampling chamber of the present invention.

Figure 8 is a diagrammatic representation of the automated baggage/parcel sampling chamber and first automated sampling head of the present invention.

Figure 9 is a diagrammatic representation of the automated baggage/parcel sampling chamber and second automated sampling head of the present invention;

Figure 10 is a diagrammatic representation of the automated baggage/parcel sampling chamber and third and fourth automated sampling heads of the present invention.

Figure 11 is a diagrammatic representation of the first sample collection and analysis subsystem of the present invention.

Figure 12 is a diagrammatic representation of the filter element configuration utilized in the first sample collection and analysis subsystem of the present invention.

Figure 13 is a cross-section of the dust canister with dust particles in a resting state.

Figure 14 is a cross-section of the dust canister with the dust particles in a fluidized state.

Figure 15 is a flow chart illustrating the overall process control.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The dust particle spraying device of the present invention is designed to enhance the detectability of plastic explosive residue by spraying a dust particle material on to a suspect surface immediately prior to collection and analysis. The enhancement of the method does not significantly reduce the speediness of detection processes. The dust sprayed has an affinity for the residue of plastic explosives

such as Semtex, C4 and DM-12, among others. The dust allows the operator of an explosive detection device to obtain an accurate result with even less residue than necessary for the detection devices to pick up without the use of the dust particles. Amounts as small as parts per trillion of residue in the entrained airstream can be detected reliably and in a speedy and non-invasive manner.

The dust spraying device of the present invention is to be used with a vacuum-type explosive detection device. Notable are systems which utilize brushes and vacuum apparatus on a conveyor belt for luggage and other containers and hand-held wand-type vacuum detection devices. Both of these types of devices are described in U.S. Patent No. 5,109,691 and U.S.S.N. 859,509 filed June 8, 1992 which were issued to and applied for by inventors Colin Corrigan and Lawrence Haley. The entire disclosures of the above-identified U.S. Patent and Application are incorporated herein by reference thereto.

It is important to note that some of the various plastic explosives or materials of interest leave "sticky residues" or "sticky particulates" on the individuals or objects that come in contact with these materials. They do not naturally vaporize or dislodge easily, and in order to remove them, it is necessary to physically sweep them from the individual or object.

The "sticky particulates" are from a particular class of target materials; namely, plastic explosives such as the military high explosive C4, DM-12, and Semtex. It is important that the particulates of these materials be collected because they exhibit extremely low vapor pressures, and are therefor not detectable with vapor detectors. Typically, these explosives have vapor pressures of 10,000 to 1,000,000

times lower than conventional explosives. Therefore, if the particulates themselves are not collected, it is virtually impossible to detect the presence of these explosives. These particular explosives cannot be handled without the sticky residue remaining on whatever comes in contact with the explosives. A complete description of this phenomenon is given in the Analysis section. However, it should be noted at this point that it is because of the sticky nature of the particulates that the wood dust is able to enhance the collection process.

HAND-HELD WAND

As illustrated in Figures 1 through 6, the hand-held wand of the present invention is a device for gathering a sample volume of air from a specific area on an individual or object such as an article of luggage and for removing particulate matter from the individual or object and introducing the particulate matter into the sample volume of air while preventing undue contamination of the sample volume of air from the ambient environment. Removal of residue of the particulate matter is enhanced by spraying the suspect surface with a fine dust prior to sampling and detection. The hand-held wand gathers a concentrated sample volume of air containing vapors and particulate matter from a specific area on the individual or object.

In a preferred embodiment, referring to Figure 1, a gas supply 1 which can be an air or other gas compressor or a source of pressurized gaseous fluid is connected via a gas supply conduit 2 which can be constructed of metal, rubber, plastic or numerous other materials to a dust canister 4 through the intermediary of an inlet orifice 3 located in the dust canister. The gas supply conduit 2 is preferably fixed on the dust canister 4 at the inlet orifice 3 by a fitting 3a,

preferably a nipple type fitting, by being pressed onto said fitting.

Extending from the inlet orifice is a fluidizer tube 9 which extends into the dust canister. As will be hereinafter further described with respect to Figures 13 and 14, the fluidizer tube 9 extends substantially into the dust canister and most preferably the fluidizer tube 9 extends about 90% of the total length of the dust canister 4. In the preferred embodiment of the present invention the inlet orifice 3 and inlet nipple fitting 3a are located at the top of the dust canister such that the fluidizer tube 9 extends toward the bottom of the canister.

In the embodiment using an air compressor, the compressor is energized by a momentary switch located on the control panel 248. When the switch is activated, the air compressor 1 begins to pump air into the dust canister 4. Air compressor 1 is set to develop 5-10 psi in the dust canister with 5 psi being preferable. In the present construction, a momentary switch is used since the ramp up of pressure from 0 to 5 psi provides a desired and controllable level of dusting. The ramp effect provides enough pressure inside the dust canister 4 to fluidize the dust therein and allow an appropriate and controlled amount to be applied to the target surface.

Upon the flow of pressurized gaseous fluid from the pressurized gas supply 1 through the gas supply conduit 2 inlet orifice 3 and fluidizing tube 9, the dust particles contained within the dust canister are fluidized. The fluidized particles are then expelled from the dust canister along with the pressurized gas through an outlet orifice 5. In the preferred embodiment outlet orifice 5 is located atop the dust canister. An exit tube 6 is provided which is fixedly

attached to an outlet fitting 5a atop the outlet orifice. Fitting 5a is preferably a nipple fitting onto which the exit tube 6 may be pressed.

Exit tube 6 is connected at its other end to an application tube 7 which is preferably constructed of metal but may be constructed of other suitable materials. In the preferred embodiment the application tube 7 is telescopic in at least one place along the length thereof such that the position of the discharge outlet may be positioned closer to or further from the dust canister at the will of the operator. Because the application tube is telescopic, the inventors have placed, in the most preferred embodiment, a collar 11 about the discharge outlet. The collar 11 is fixedly attached thereto and prevents the extendible telescopic 7a portion of the application tube 7 from being lost inside the larger telescopic portion 7b when the application tube 7 is retracted.

The lid of the dust canister can be of any type capable of withstanding the pressure created inside the dust canister by the influx of pressurized gas from the gas supply conduit 2. Possible examples are a screw-on type lid, a latch-on type lid or a pop-on type lid. Since gas pressure is only on the order of 5-10 psi, the lid type is not critical.

The dust utilized in the present invention can be of a variety of types, within the parameters of 5-50 microns as above named, with wood powder being preferred. Wood powder has an affinity for the compounds left behind in the residue of plastic explosives left on hands, clothing and surfaces by one who has handled the explosive material. Because of this affinity, the particles of plastic explosive residing on any of the above-mentioned surfaces adhere to the wood

powder dust and so can be more easily vacuumed up with a vacuum collection device explosive detection system.

While all wood dust was found to be useful in enhancing the detectability of plastic explosive material compounds, the most preferred embodiment of the present invention utilizes oak powder particles since oak emphatically evinces a greater affinity than other particles for the compounds sought.

The above described apparatus can be used in connection with a vacuum collection and detection device, most efficiently by mounting the dust spraying apparatus on the vacuum head of the vacuum collection and detection device. This facilitates the use of the present invention by eliminating the need to switch units in the operators hands. In order to mount the dust spraying apparatus brackets 31, 32 are used, which are diagrammatically illustrated in Figure 1. It should be noted that the embodiment of Figure 1 is illustrative and the dusting apparatus could be mounted in many different ways and positions. In the preferred embodiment with the dust spraying apparatus underneath the vacuum nozzle and mounted there, it is easy for the operator to first spray dust on the suspect surface and then vacuum that dust and the plastique residue adhered to it.

Referring to Figures 4a, 4b and 4c, the sampling nozzle on the hand-held wand 19 is shown in three stages of operation. The nozzle may be used as a vacuum head 28 alone or as a vacuum head 28 with a rotating brush 14. This dual ability is achieved through the use of an operable perforated cover 26 made up of four pieces. There are two side sections numbered 20a, 20b and two top sections numbered 21a, 21b. The operation of the preferred cover 26 is best understood simply by viewing drawing Figures 4a, 4b and 4c. These

figures show the preferred cov r moving from the fully open position (Figure 4a) to a partially open (Figure 4b) to fully closed (Figure 4c). The cover is moved by sliding the gliding sleeve 18 forward or away from suction end 27 of the vacuum head 28. Moving the sliding sleeve 18 toward the suction end 27 closes the perforated cover 26; reversing the direction of movement reverses the process. The cover has six pivot points which work in concert upon movement of the sliding sleeve 18 to produce the desired function. Anchoring pins 23 are fixed or wand 19 relative to the sampling nozzle orifice 27. These are the only two pivot points on the perforated cover which do not change position and thus are responsible for the cover responding to the movement of sliding sleeve 18. Two of the remaining four pivot points are illustrated in Figure 3 by numerals 24a and 25a, these points are a mirror image of the pins 24b and 25b on the opposite side of the perforated cover 26. Pivot point 24a joins one side of the top section 21 of cover 26 to the corresponding side section 20 of cover 26. Pivot point 25a joins side section 20 of cover 26 to slide sleeve 18. Starting with cover 26 in an open position, moving sliding sleeve 18 toward suction end 27 of the vacuum head 28 begins a linear movement of sections 20 and 21. However, because sections 21 are anchored by anchoring pins 23, sections 21 are forced to move in an arcuate pattern until they meet at the midline of the vacuum head 28. Sections 21 meet the midline after they have moved through 90° of an arc.

Referring to Figures 5 and 6, a cross-sectional view of the vacuum head 28 is provided. This figure illustrates a very important aspect of the vacuum head. The rotating brush 14 is important to the functionality of the detector system since it brushes

the target surfaces as it rotates and thereby tends to loosen particulate matter which has adhered to the target surface. The brush 14 is spring mounted on a splined shaft 15. The shaft is extendable and retractable into a splined receptacle 16 which is driven by turbine 13. The brush 14 is normally spring biased into contact with the target surface. However, if excessive force is placed upon the brush 14, the spring bias will be overcome and the brush will retract into the vacuum head.

The brush illustrated in Figure 5 is composed of toothbrush like bristles. The bristles, while naturally having a point or rounded head, are forced into a splayed formation by a wedge which is driven into the center of the shaft on which the bristles are mounted. The bristles can be made of numerous materials but preferably are made of plastic.

The air turbine 13 is located in the vacuum head 28 and is driven by the flow of air over the turbine blades of the turbine 13. The air flow which drives the turbine 13 is caused by a suction fan located in the sample collection and analytical subsystem. This suction fan is utilized to draw the sample volume of air during a sampling period. A complete description of the sampling procedure is given in detail in subsequent sections. The effect of the sweeping action and the drawing of the sample volume of air combines to create a sample volume of air containing both vapors and particulate matter.

The suction fan utilized to draw the sample volume of air is capable of developing a flow rate of 70 to 85 CFM. This flow rate translates into a vacuum capable of raising 115 to 140 inches of water when the hand-held wand is sealed against the side of a piece of luggage, and a vacuum capable of raising 33 to 40 inches

of water when the hand-held wand is opened to the ambient environment through a one inch orifice.

Referring to Figure 1, the vacuum head 28 is connected to the handle 240 through a conduit 224. The conduit 224 connects the hand-held wand to the sample collection and analytical subsystems and acts to transport the sample volume of air collected to these subsystems for concentration and vaporization.

The handle 240 is mounted on pipe 224. There is also a grip section 244 onto which a user will hold. A control cable 246 runs through the grip section 244 and carries all the control and signal display wires from the control and data processing system, to be discussed subsequently, to the controls and displays of the hand-held wand 200. Figure 1 illustrates a side view of the hand-held wand 200 and shows the control panel 248 and the display panel 250 while Figure 2 illustrates a plan or top view. The controls and displays may be utilized to operate the detection screening system from a remote location.

The control panel 248 comprises control switches used to actuate a single cycle function, a continuous cycle function, a pause function and the reset function of the detection, screening system and activation of the pressurized gaseous fluid supply 1. The single cycle, continuous cycle, and pause functions are associated with the collection of the target materials. The reset function is utilized to reinitialize the system after an alarm condition. The display panel 250 comprises an alarm display area and a numeric display area. The alarm display area is used to indicate whether a target material has been detected by the sample collection and analysis subsystem. Additionally, the alarm display comprises an audio alarm which indicates to the system user that a target

compound has been detected. The numeric display area is normally used to display an identification number associated with the sample being taken, but may also be used to display the identification number of the sample which triggered the alarm.

AUTOMATED BAGGAGE/PARCEL SAMPLING CHAMBER

The automated baggage/parcel sampling chamber is a device for gathering a sample volume of air surrounding an object and for dusting and removing particulate matter from all exposed surfaces of the object and introducing the particulate matter into the sample volume of air. Like the hand-held wand, the automated baggage/parcel sampling chamber spray the luggage with a fine dust and then gathers a concentrated sample volume of air containing vapors and particulate matter. As is the case with the hand-held wand, the automated baggage/parcel sampling chamber has means for gathering the sample volume of air directly from the object.

Referring to Figure 7, there is shown the basic configuration of the automated baggage/parcel sampling chamber 300. The automated baggage/parcel sampling chamber 300 is a rectangular open ended tunnel structure. The size of the chamber 300 may vary, however, for convenience the size of the chamber 300 is chosen to match that of a baggage scanning x-ray device of the kind presently used in airports. In this embodiment, the automated baggage/parcel sampling chamber 300 is approximately six feet in length, 38 inches in width and 32 inches in height. The automated baggage/parcel sampling chamber 300 is fitted over a conveyor belt 350 which is utilized to carry the baggage or parcels through the chamber 300 at a rate of speed that would enable the baggage or parcels to be sampled for a duration ranging between approximately three to

seven seconds although the range may be extended if desired. At least one and pr ferably several dust discharge nozzles 371-374 are located at the entrance of the sampling chamber 300; the nozzles are fed by a manifold 375. The manifold 375 provides for dust to be applied on the top and the sides of the chamber so baggage is fully coated. It will be understood that one or more nozzles can be used, all of which being fed by the manifold shown in Figure 7. These spray the fine wood dust on to the target surfaces of luggage passing therethrough which is then collected by the sampling heads discussed hereunder. In Figure 7, an additional four air nozzles 381, 382, 383 and 384 are also illustrated. The air nozzels are fed with high pressure air and serve to agitate and dislodge the dust particles and adhered particulate prior to collection and analysis. The automated baggage/parcel sampling chamber 300 also comprises at least four automated sampling heads 310, 320, 330, and 340 which are utilized to gather the sample volume of air.

The four automated sampling heads 310, 320, 330, and 340 each contain rotating brushes which are utilized in combination with the high speed air jets 381-384 to remove the dust and "sticky" particulates from the luggage or other object of interest. The first automated sampling head 310 is located at the entrance of the chamber 300 immediately before the conveyor belt 350 as shown in Figure 8. The inlet of the first automated sampling head 310 extends the entire width of the chamber 300 and is set so that the rotating brush gently sweeps and draws vapors, dust and particulates from the bottom of the baggage or parcel 302 as it is pushed onto the conveyor belt 350. As was stated previously, the various materials of interest leave a "sticky residue" on the objects they come in contact

with, which attracts and holds the dust. When the dust is swept from the object it carries with it the sticky residue or particulate matter which may then be concentrated and analyzed. The first automated sampling head 310 is valve connected to a common plenum (not shown) through a pipe or conduit 312.

The second automated sampling head 320 is hingedly connected to the roof of the sampling chamber 300 inside the entrance of the chamber 300. A representation example of a typical sampling head 320 is shown in Figure 9. The inlet of the second automated sampling head 320 extends the entire width of the sampling chamber 300, and as the baggage or parcel 302 moves through the sampling chamber 300, the second sampling head 320 sweeps and draws vapors from the top portions of the baggage or parcel 302. The second automated sampling head 320 is connected to the roof of the sampling chamber 300 by two pairs of paralever arms 321 and 323. First and second offset springs 325 and 327 are attached between each set of paralever arms 321 and 323 in order to bias the sampling head into the path of the luggage, and provide tension between the sampling head 320 and the baggage or parcel 302 as it travels through the chamber. The offset springs 325 and 327 maintain the second automated sampling head 320 in firm contact with the baggage or parcel 302 as the paralever arms 321 and 323 are forced upward. The second automated sampling head 320 is valve connected to the common plenum through a pipe or conduit 322.

As illustrated in Figure 10, the third and fourth automated sampling heads 330 and 340 are hinged connected on opposite sides of the sampling chamber 300 so as to not interfere with the second automated sampling head 320. The third and fourth sampling heads 330 and 340 automatically adjust to the width of the

baggage or parcel 302, by spring loading or by the use of sensors and servos (not shown), in a manner such that the sides of the baggage or parcel 302 are gently swept by the sampling heads. The third and fourth sampling heads 330 and 340 are valve connected to the common manifold through pipes or conduits 332 and 342.

The sampling of a piece of baggage or parcel preferably involves three sampling procedures. First, the baggage or parcel 302 moves into the entrance to the sampling chamber 300 and is treated with dust from nozzles 371-374; second, the baggage parcel 302 moves across the first automated sampling head 310 located several inches within the entrance of the sampling chamber 300. During this process, the suction and air flow generated by the suction fan located in the sample collection and analytical subsystem is totally dedicated to this sampling head 320. The explosion detection system (not shown) at this sampling step provides for particulate collection and vaporization and vapor adsorption and concentration, while the detection means include both gas chromatography and IMS detection. At a second sampling step, the side automated sampling head 330 is activated. When the baggage or parcel reaches a set point in the sampling chamber 300, the second sampling head 320 is activated by its sensor. The air flow and suction from the second automated sampling head 330 is directed to a particulate collection and vaporization (PCAD) unit with an IMS detector. Simultaneously, the third sampling head 340 is also activated. Air samples from sampling head 340 are also directed to a particulate collection and vaporization (PCAD) unit with an IMS detector.

The vacuum fan utilized to draw the sample vapors, dust and particulates in the sample volume of air is capable of developing a flow rate of 70 to 85 CFM

at each sampling head, which enable the sampling heads to draw vapors through the seams and closure joints of the baggage. It will also draw vapors through cloth and vinyl suitcases as well as through the plastic material used to conceal explosives. The determination of whether a meaningful sample of vapors has been gathered depends upon the concentration of the initial sample and the porosity of the particular container.

The manifolds are connected to the first, second and third sample collection and analytical subsystems. In one embodiment, the sample volume of air collected by each automated sampling head 310, 320, 330, and 340 may be directly sent to a single sample collection and analytical subsystem.

SAMPLE COLLECTION AND ANALYTICAL SUBSYSTEM

The sample collection and analysis subsystem 400, shown in Figure 11, is the particulate collector and detector, hereinafter the PCAD system. It is located in line directly after the sampling means, which may be the hand-held wand, or the automated baggage/parcel sampling chamber. The PCAD 400 is comprised of the sample collector and vaporizer 410 (hereinafter the SCAV), which adsorbs vapors and particles and then vaporizes the sample and a chemical analyzer 460 which may be either a gas chromatograph/electron capture detector(s), GC/ECD, or an ion mobility spectrometer, IMS or both. The PCAD 400 is used to collect and analyze particulates in a sample volume of air collected in one of the two sampling means for the chemical compounds of interest.

SAMPLE COLLECTOR AND VAPORIZER (SCAV)

The SCAV 410 is located in line between either of the two sampling means and analyzer 460. The SCAV 410 is used to collect and vaporize particulate samples from an air stream as it moves from one of the two

sampling means to the analyzer 460. The SCAV 410 is supplied with the air stream by a pipe 224 which extends and connects to either of the two sampling means. During sampling periods a high suction fan 404 draws the sample volume of air from one of the two sampling means thereby causing the air stream to flow into the SCAV 410. The suction fan 404 is connected to pipe 402 on the suction side, and the discharge of the fan 404 is connected to a vent or exhaust system to the ambient environment. A second concentrating subsystem may also be provided to further concentrate vapor emissions from the SCAV.

The SCAV 410 comprises a rotating circular plate 412, a collection chamber 414, a vaporization chamber 416, and a cleaning chamber 418. The collection, vaporization and cleaning chambers 414, 416, and 418 are formed from the union of first and second fixed SCAV plates 420 and 422. The first and second fixed SCAV plates 420 and 422 each comprise approximately one half of the volume of each of the three chambers 414, 416, and 418. As illustrated in Figure 12, the first and second fixed SCAV plates 420 and 422 are aligned such that the collection chamber 414, the vaporization chamber 416 and the cleaning chamber 418 are configured 120 degrees apart from each other. The rotating circular plate 412 is disposed between the first and second fixed plates 420 and 422 and is mounted for rotation therebetween. The rotating circular plate 412 has three circular holes 412a, b and c equally spaced 120 degrees apart and covered with three mesh filter elements 426a, b and c. The configuration of the three filter elements 426a, b and c on the rotating circular plate 412 is shown in Figure 12. The rotating circular plate 412, is rotated by a motor 428, through 120 degrees of rotation during every

sampling period so that each of the mesh filter elements 426a, b, and c occupies one of the collection chamber 414, the vaporization chamber 416 or the cleaning chamber 418 during any given sampling period. The motor 428 utilized to rotate the rotating circular plate 412 is a gear head motor which is controlled by the PCAD actuator unit which is part of the control and data processing system. A stepper motor can also be utilized. On completion of each rotation, a lever mechanism 432, which is actuated by a solenoid 430, pulls the first and second fixed SCAV plates 420 and 422 together so that each of the three filter elements 426a, b, and c are sealed in either of the three chambers 414, 416, and 418 during a particular sampling period. The solenoid 430 and the lever mechanism 432 are controlled by the PCAD actuator unit. The three filter elements 426a, b, and c are completely sealed, in an air tight fashion, in each of the three chambers 414, 416, and 418. The air tight seal is accomplished by O-ring seals which surround each of the three chambers 414, 416, and 418. The O-ring seals are placed around the perimeter of the chambers, or more accurately, around each of the half chambers in each of the first and second fixed SCAV plates 420 and 422. To completely illustrate the design and operation of the SCAV 410, a complete 360 degree rotation of the rotating circular plate 412 is described.

Referring to Figure 12, a rotatable plate with three removable filter elements is illustrated. The adsorbent material used in the insertion may be selected from a vast group of materials commonly used for vapor sampling including tenax and carbotrap. Other adsorbent material may be used depending on the particular materials that are to be detected and isolated. The filter elements are inserted into the

edge of rotating plate 412 with the hole in the filter element aligned with the hole of the filter unit as illustrated. Entrance to each filter cavity is from the circumference of the rotating circular plate 412. Each of the sample filter elements 426a, b, or c is uniquely designed to facilitate electrical current conduction, and as well as a gas tight fit while still providing for easy insertion and removal.

To illustrate the three sampling periods which corresponds to one 360 degree rotation of the rotating circular plate 412, it is necessary to state or assume that filter element 426a is inside the collection chamber 414, filter element 426b is inside the vaporization chamber 416, and filter element 426c is inside the cleaning chamber 418 at the system start-up time. In this position, the filter element 426a and hole 412a are directly in line with pipe 402 and thus filter element 426a is capable of selectively collecting, or more precisely, physically trapping dust and target particulates which are drawn from either of the two sampling means during a sampling period. The particulate matter drawn in is physically trapped or adsorbed on filter element 426a. Vapors collected by either of the two sampling means pass through the filter element 426a and may be preferentially retained by the filter element 426 as will be hereinafter explained in greater detail. The filter elements 426a b, and c can be varied in mesh size so as to be able to collect specific size particulates and still allow the air to pass easily therethrough. Upon completion of this first sampling period, the solenoid 430 is actuated by the control and data processing system thereby causing lever mechanism 432 to separate the first and second fixed SCAV plates 420 and 422. Once the separation of the first and second fixed SCAV plates 420 and 422 is

completed, the gear head motor 428 is engaged by the PCAD actuator unit of the control and data processing system and rotates the circular plate 412 120 degrees, placing filter element 426a, with trapped particulates and vapor, inside the vaporization chamber 416 while filter element 426b is placed inside the cleaning chamber 418 and filter element 426c is placed inside the collection chamber 414.

The vaporization chamber 416 is a sealed chamber which contains a pair of electrical terminals 413 which connect to filter element 426a when that particular filter element occupies the vaporization chamber 416. The pair of electrical terminals 413 provide a computer controlled current directly to the filter element 426a in order to generate a specific amount of ohmic heat energy to effectively vaporize the collected particulate matter and desorb any vapors retained by the coating on the screen. The current is controlled by the control and data processing system. Through experimentation, it has been established that a flash heat of 50-200 millisecond duration, with 75 to 100 milliseconds preferred, vaporizes the targeted materials and creates an instantaneous increase in gas pressure within the vaporization chamber 416 of very short duration which acts to aid in the vaporization and injection of a controlled volume of the sample into the chemical analyzer 460. As the flash heating and vaporization is taking place a small quantity of carrier gas from gas supply means 434 is continuously fed into the vaporization chamber 416 via gas line 436. The gas flow is used to sweep or carry the molecules from the vaporized particulates into the chemical analyzer 460. In the preferred embodiment, the gas utilized is an inert gas; however, other non-reactive gases can be utilized. In one embodiment, the vaporization chamber

416 is connected directly to the chemical analyzer 460 and the carrier gas sweeps the vaporized material or first sample volume directly into the chemical analyzer 460, and in a second embodiment, a three-way valve 438 is utilized as an interface between the vaporization chamber 416 and the chemical analyzer 460. Pipe 437 carries the sample volume from the vaporization chamber 416 to the chemical analyzer 460 either directly or through the three way valve 438.

If a gas chromatograph/electron capture detector is utilized as the chemical analyzer 460, a six-port valve may be added as an interface between the vaporization chamber 416 and the chemical analyzer 460. A suitable six-port valve is described in U.S. Patent 5,109,691. In this embodiment, the vaporization process is identical to that previously described; however, the carrier gas sweeps the vaporized material into the six-port valve instead of directly to the chemical analyzer 460 or through the three-way valve 438. The six-port valve is used to separate more volatile and less volatile vapors from the vaporized sample, and to preferentially retain the vapor sample of interest for separation by the GC. This venting of unwanted vapors is desirable to avoid clogging the GC, or unduly extending the cycle time.

ANALYSIS

The analysis of the purified target material consists of identifying the materials and determining the amounts present. Because the original concentrations are low with respect to many other common ambient materials it is possible for there to be, even under the best of purification and concentration systems, some remaining impurities of materials with similar characteristics to the target materials. Thus the analysis system must be capable of separating the target material response from the response due to interfering materials.

Two forms of analysis systems may be used either separately or in combination. The first particle collection and analysis subsystem 400 utilizes an ion mobility spectrometer, a gas chromatograph/electron capture detector, or both. The final detector for the gas chromatograph is usually an electron capture detector, however the ion mobility spectrometer can also be used as the second detector if desired. Depending on the application, a photo ionization detector or a nitrogen-phosphorus detector or some other detector may be also used following the gas chromatograph. The gas chromatograph may be of the "packed column" type or the capillary column type. If both a gas chromatograph/ electron capture detector and ion mobility spectrometer are utilized, they can be used separately or in a combined fashion. A valve can be utilized to direct the collected and purified sample to either or both of the analyzers.

In the preferred embodiment, an ion mobility spectrometer is the analyzer 460. The particulate collection and analyzer 400 is used to collect particulates and vaporize these particulates for chemical analysis. The particulates of interest are

associated with plastique explosives such as C4, DM-12, and Semtex. As was stated previously, plastique explosives have extremely low vapor pressures ranging from 10,000 to 1,000,000 times less than that of conventional explosives such as dynamite, nitroglycerin, and trinitrotoluene. The analysis of these particulates is based upon the detection of certain signature molecules. For plastique explosives, these signature molecules are cyclotrimethylenetrinitramine, RDX, or pentaerythritol tetranitrate, PETN. The ion mobility spectrometer is set to detect these signature molecules by creating a sample window for each of them. A window is utilized as opposed to trying to develop a direct match because one cannot expect a pure sample of the signature molecule. If a particular compound analyzed fits into one of the above windows, the sample sampled is deemed to have been in contact with a plastique explosive.

There are presently a variety of international groups including national security agencies, the military and international manufacturers of explosives, that are working or deciding on a particular tagent to be added to all explosives so that they may be more readily detected. The particular tagent that is decided upon will become one of the signature molecules that will be searched for in the analysis phase of the explosive screening process. A list of the signature molecules currently tested for is given in Table 1 set forth below. The table indicates the name, code, formula and use of each compound. Explosives are typically categorized as primary, secondary, or high explosives and propellants in order of decreasing sensitivity to energy input. In other words a primary explosive is more sensitive to heat for example, than a secondary explosive.

TABLE 1

Name	Code	Formula	Use
ethylene glycol dinitrate	EGDN	$O_2NOCH_2CH_2ONO_2$	liquid explosive
nitroglycerin	NG	H_2CONO_2 $HCONO_2$ H_2CONO_2	liquid secondary explosive ingredient in commercial explosives and propellants
2,4,6 - trinitrotoluene	TNT	CH_3 O_2N NO_2 NO_2	secondary high explosive
cyclotrimethylene trinitramine	RDX	NO_2 N N N O_2N NO_2	secondary high explosive used as a booster
pentaerythritol tetranitrate	PETN	O_2NOCH_2 CH_2ONO_2 C O_2NOCH_2 CH_2ONO_2	secondary high explosive used as a booster

Whatever analysis system is used, the analysis must be completed in a time that is short enough that the free flow of people, luggage and baggage is not unduly inhibited. This also implies that the time for the concentration and purification process is short as well.

If all the valves in the system are motor driven or solenoid driven valves, the flow directions timings and magnitude may be controlled and varied. The time and temperature parameters are controlled and variable. Thus the physical characteristics of the complete system may be adjusted to detect a wide range of target materials and the sensitivities may be adjusted to accommodate a wide range of threats as perceived by the authorities using the system.

As was above stated, the systems described herein are greatly enhanced by the addition of a method and device utilizing wood dust as a pretreatment to vacuum detection. The wood dust acts as a carrier material having an affinity for plastic explosive compounds. Therefore, the wood dust acts as a carrier material helping to bring particulate matter from the target orifice into the detection system.

It has been found by the inventors that wood dust in particulate form and on the order of 5-50 microns (μm) in diameter are preferred. The device for applying the wood dust is described in the following paragraphs.

The use of the method and apparatus of the invention has produced surprisingly superior results as is indicated by the following comparative tests. In each case a residue was provided intentionally on a subject surface and detection tests were performed for each example a detection test was done first without the aid of wood dust particles and then repeated after treating the subject surface with wood dust particles before vacuuming the same.

Comparative Test 1

A closed container 102" X 60" X 60" was used in which the surface area of boxes were contaminated with fingerprints of Semtex, C4 and DM-12. Air samples were then taken without the aid of wood dust particles. Each air sample was taken by inserting the sampling hose of a vacuum detection device called an Explosives Detection Security System general purpose scanner through a sealed orifice into the closed container above specified. In each case the analysis of the samples taken did not detect the presence of any of the plastic explosives' compounds.

The container was then treated by spraying wood dust in an air jet stream into the container. The boxes were then agitated and further vacuuming samples, identical to the above, except for the latter presence of wood dust, were taken.

Positive test results were obtained for all of the air samples taken after wood dust had been applied.

Comparative Test 2

In this test, the inventors simulated a baggage conveyor system similar to that illustrated in Figures 7 through 9. The baggage had fingerprints thereon which contained traces of Semtex, C4 and DM-12. The baggage was moved through a chamber on a conveyor belt at a rate of twelve inches per second and an EDSS™ general purpose scanner was used to take samples of the surrounding environment to detect the presence of compounds associated with plastique. Test results revealed only sporadic detection whereas the same type test performed after the baggage had been treated with wood dust achieved 100% accuracy.

Comparative Test 3

In this test a test subject placed his thumb on Semtex, C4 and DM-12 and then placed his thumb in each of 28 squares so as to leave a fingerprint in each square.

An EDSS™ general purpose scanner was then used to determine in which squares the explosive compounds could be detected. The results were that detection occurred sporadically from the 15th square downward. However, when the same fingerprints were treated with the sprayed-on wood dust, detection of the explosive compounds tended to occur at the 28th square, thus evidencing a far greater sensitivity than without the wood dust.

CONTROL AND DATA PROCESSING

The primary requirement for the control and data processing system of the screening system is that is reports the presence of, and if required, the level of specified substances. This means that the equipment must be configured and controlled to make the required measurement and it also means that the result must be presented to the user in a usable form. The subject or target materials may be present in varying amounts in the environment of the system and therefore, the system must be capable of distinguishing between this background level and an alarm level. It may also be a requirement to report on this background level.

Figure 15 is a flow chart 800 showing the overall process control as accomplished by the control and data processing system and run by a digital computer in the detection system. A complete description of the operation of the process control is provided in U.S.S.N. 859,509, filed June 8, 1992. Block 802 of the flow chart 800 is simply the starting point or entry into the entire software process. The Run Diagnostics block 804 represents the block of software that is responsible for self diagnostic and self calibration. Basically, this block of software runs various programs for exercising various aspects of the detection and analysis routines. The Sample Air and Enable Camera block 806 represents the block of software that causes the air sample to be drawn

from the hand-held wand or the automated baggage/parcel sampling chamber, and drawn into the sample collection and analytical subsystems. The Sample Air and Enable Camera block 806 also represents the block of software responsible for enabling a camera to capture an image of an object or individual being sampled. The captured image is then correlated to the chemical analysis data associated with the sample drawn from the individual or object and is then saved in memory for an archival record to be used as an identification means.

After the Sample Air and Enable Camera block 806, the flow chart 800 steps to the rotate PCAD Filters block 808, which represents the block of software that is responsible for the rotation of the rotating circular plate and the union and separation of the first and second fixed plates. The Heat Collected Particulate Matter block 810 represents the block of software that is responsible for the controlling of the vaporization process. This block of software controls the flash heating process as well as the gas flows utilized to inject the vaporized sample into the chemical analyzer.

The Acquire Data block 812 represents the block of software that is responsible for the acquisition of data from the chemical analyzer(s) and the subsequent analysis and preparation for display of the resultant data. In addition, this block of software correlates the collected data with an index representation of the image of the individual or objects captured by the camera means.

The Display Data/Camera Picture block 822 represents the block 822 represents the block of software that is responsible for formatting the acquired chemical analysis data in a format that is readily displayed on a standard CRT and is easily understood. The captured image or picture can also be displayed utilizing standard display techniques. The entire software structure

indicated in Figure 15 is a cyclic process and following the step of block 822, returns to the Sample Air and Enable Camera block 806 and continues until stopped. The software further enables the system to run in a single cycle mode, a continuous cycle mode or a pause mode. As stated previously, the software routine is modularized and therefore can be easily changed, updated, removed or added on to.

The flow chart of Figure 15 is a general representation of the software and should not be construed as a timing diagram. Table 2 given below illustrates the required steps and associated times involved in the screening procedure.

TABLE 2

STEP	PCAD
SAMPLE AIR	2.0
ROTATE FILTERS	1.0
VAPORIZE/DESORB	0.25-0.5
INJECTION	0.25-0.5
ANALYSIS AND DISPLAY	1.0 AND 0.75

It is important to note that the times given in Table 2 reflect the absolute times for each of the processes and do not reflect the total time for one sampling cycle since the step of sampling and the steps of vaporizing are carried on simultaneously in separate chambers in the device.

Although shown and described in what is believed to be the most practical and preferred embodiments, it is apparent that departures from specific methods and designs described and shown will suggest themselves to those skilled in the art and may be used without departing from the spirit and scope of the invention. The present

invention is not restricted to the particular constructions described and illustrated, but should be constructed to cover all modifications that may fall within the scope of the appended claims.

WHAT IS CLAIMED IS:

1. A portable explosive detection screening syst m for the detection of concealed selected target materials such as plastic explosives, chemical agents and other controlled substances by detecting their vapor or residual particulates, said system comprising:

(a) a portable dusting means for pretreating a suspect surface with dust to enhance collection of residual particulates of said target materials;

(b) a sampling means for gathering a sample volume of air from a specific area to collect any vapor or residual particulates therefrom, said sample drawn by a suction fan;

(c) a concentrator means to selectively retain vapors or particulates in said sample volume of air, said concentrator including first, second and third filtering means with each filter means sequentially movable between an adsorption position, a vaporization position, and a thermal cleaning position, said second filter means being in said vaporization position when said first filter means is in said adsorption position and when said third filter means is in said thermal cleaning position, said vaporization position having means to heat said filter to desorb said vapor and to vaporize any collected residual particulates; and

(d) a detecting means having a least a first detector responsive to vapor desorbed from said concentrator to generate a first signal and an alarm.

2. A portable explosive detection screening system as claimed in claim 1 wherein the sampling means includes a hand-held wand.

3. A portable explosive detection screening system as claimed in claim 1 wherein the sampling means is a sampling chamber.

4. A portable explosive detection screening system as claimed in claim 1, wherein said portable dusting means includes:

(a) a dust canister having an inlet orifice and an outlet orifice;

(b) a pressurized gaseous fluid supply connected to said inlet for pressurizing said canister;

(c) a discharge orifice connected to said outlet to selectively direct the discharge of particles of dust from said canister onto a target surface.

5. A portable explosive detection screening system as claimed in claim 4 wherein the pressurized gaseous fluid supply is an air compressor.

6. A portable explosive detection screening system as claimed in claim 5 which further includes a momentary switch for actuating said air compressor.

7. A portable explosive detection screening system as claimed in claim 4 wherein the discharge orifice is mounted on a telescopic application tube.

8. A portable explosive detection screening system as claimed in claim 1 wherein the dust is wood dust.

9. A portable explosive detection screening system as claimed in claim 8 wherein the wood dust is oak dust.

10. A portable explosive detection screening system as claimed in claim 8 wherein the dust has a particle size of 5-50 microns.

11. A portable explosive detection screening system as claimed in claim 1 wherein the sampling means includes a hand-held wand having a sampling nozzle, said nozzle comprising:

(a) a hollow cylindrical wand having an open end and first and second anchoring pins which extend radially outward from the wand proximate the open end;

(b) a sliding sleeve disposed around and closely proximate to the open end;

(c) first and second perforated multi-section covers pivotally attached to the sliding sleeve and disposed concentrically around the hollow wand;

(d) a rotating brush mounted for rotation within said hollow wand; and

(e) a turbine mounted within said wand to rotate the brush.

12. A portable explosive detection screening system as claimed in claim 11 wherein each of the first and second perforated multi-section covers has a top section and two side sections pivotally mounted such that the two top sections and two side sections act in concert to expose the brush when actuated by the sliding sleeve.

13. A portable explosive detection screening system as claimed in claim 12 wherein one top section and one side section of the perforated cover are hingedly connected such that each top section can arcuately rotate about the anchoring pins when the top sections are urged in either an opening or closing motion by the side sections upon motion of the sliding sleeve.

14. A portable explosive detection screening system as claimed in claim 11 wherein the brush includes bristles which are splayed about a center zone of said nozzle.

15. A portable explosive detection screening system as claimed in claim 14 wherein the brush is mounted for reciprocal mount within said wand, and resiliently biased to a position extending beyond the wand.

16. A portable explosive detection screening system as claimed in claim 11 wherein said turbine is rotated by an air stream in said wand.

17. A portable explosive detection screening system as claimed in claim 1 wherein the suction fan generates an air flow of 70-85 cfm.

18. A method for enhancing the sensitivity of a vacuum explosive detection system for selected target residue of molecules and particulates, comprising the steps of:

(a) treating a selected surface suspected of having a target residue thereon with dust;

(b) collecting the dust and any residual explosive particulates of said target on the selected surface with a vacuum sampling means;

(c) concentrating the target materials by adsorption, collection and selective vaporization; and

(d) analyzing the vapors produced in said vaporization stage for the presence of said target molecules.

19. A method for enhancing the sensitivity of a explosive detection system according to claim 18 wherein the treating step comprises the step of spraying a dust material onto a selected surface suspected of having residue of target particulates thereon.

20. A method for enhancing the sensitivity of an vacuum explosive detection system according to claim 21 wherein the dust material sprayed is a wood dust.

21. A method for enhancing the sensitivity of an explosive detection system according to claim 20 wherein the wood dust sprayed is oak dust.

22. A method for enhancing the sensitivity of an explosive detection system according to claim 19 wherein the dust has a particle size of 5-50 microns.

23. A method for enhancing the sensitivity of an explosive detection system according to claim 19 wherein the dust is sprayed at a pressure of 0-5 psi.

24. A vacuum head for a hand-held wand used with a portable explosive detection system, said h ad comprising:

(a) a hollow wand for collecting a sample of air containing vapors and residual particulates of explosive materials for analysis by a portable explosive detection system, said wand defining a longitudinal axis and a vacuum orifice;

(b) a brush mounted within said vacuum orifice for rotation about said longitudinal axis, said brush mounted for reciprocal mount along said axis and resiliently biased in to a first position with said brush protruding beyond said vacuum orifice, said brush cooperating with air flow though said orifice to collect said vapors and residual particulates of said materials;

(c) a turbine means mounted in said wand to rotate said brush, said turbine driven by air flow though said vacuum orifice; and

(d) a perforated cover for selectively covering said vacuum orifice, said cover moveably from a first open position which exposes said brush to a second closed position which may be used for selective vacuum sampling of soft fabric surfaces.

25. A method of deteching target materials including low vapor plastic explosives concealed within a standard airline container comprising:

(a) injecting dust into a closed standard airline container with an air jet;

(b) agitating the container;

(c) withdrawing at least one sample from within the container with a sampling means to collect and trained dust and explosive particulates;

(d) collecting and concentrating said sample;

(e) analyzing said sample for targent materials within said sample; and

(f) generating an alarm signal.

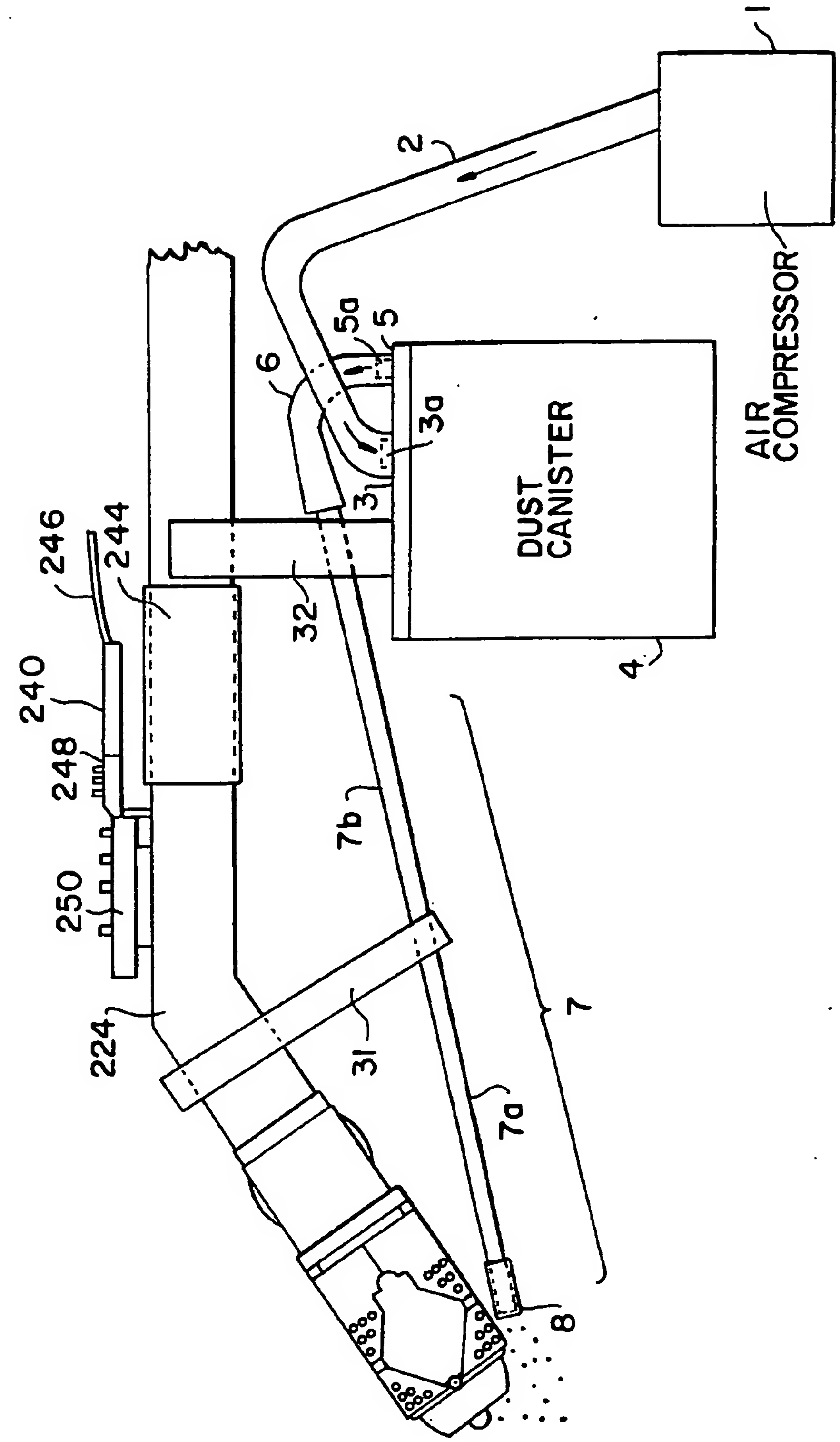
1
2
AIR COMPRESSOR
DUST CANISTER
3
3a
4
5
5a
6
7
7a
7b
8
31
32
224
240
244
246
248
250

FIG.1

FIG. 2

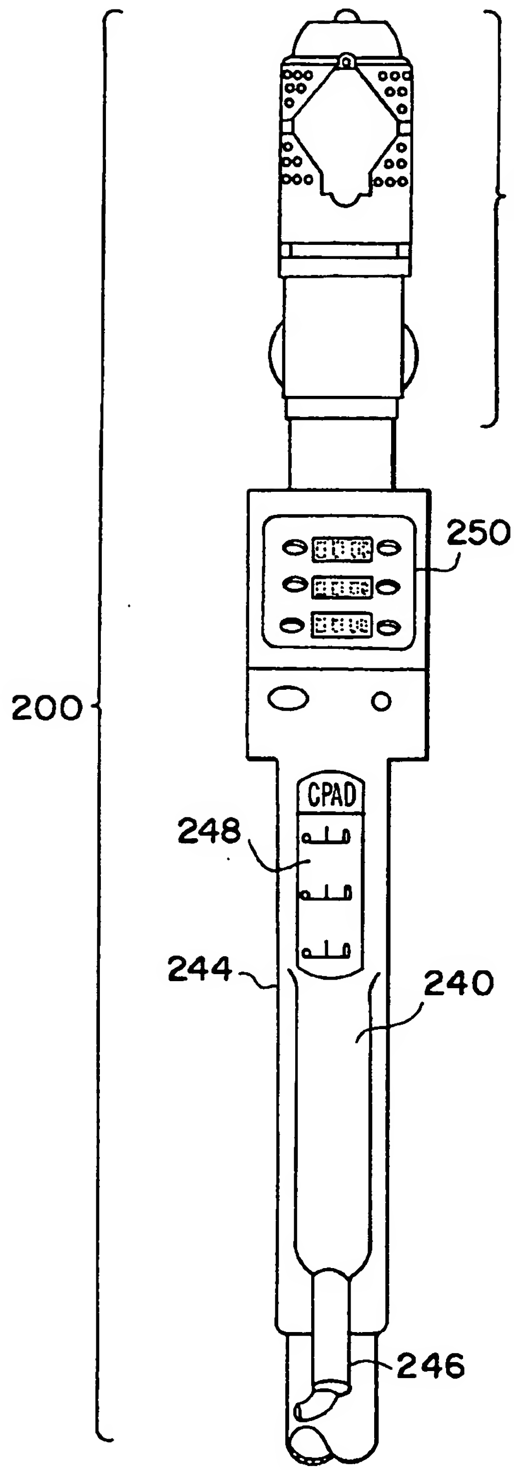

FIG. 3a

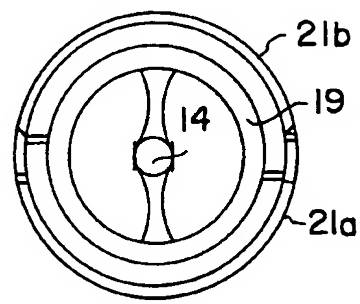

FIG. 3b

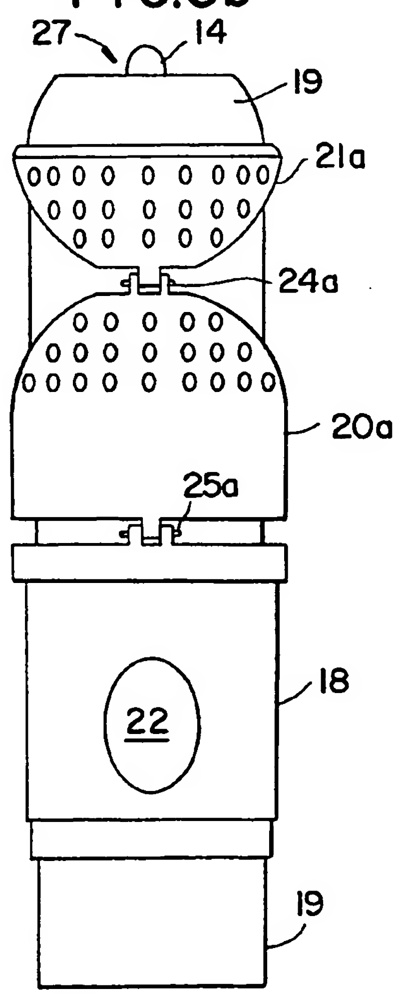

FIG.4a

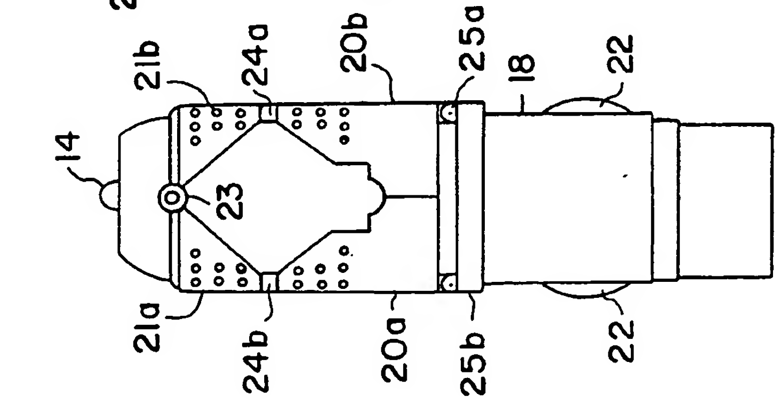

FIG.4b

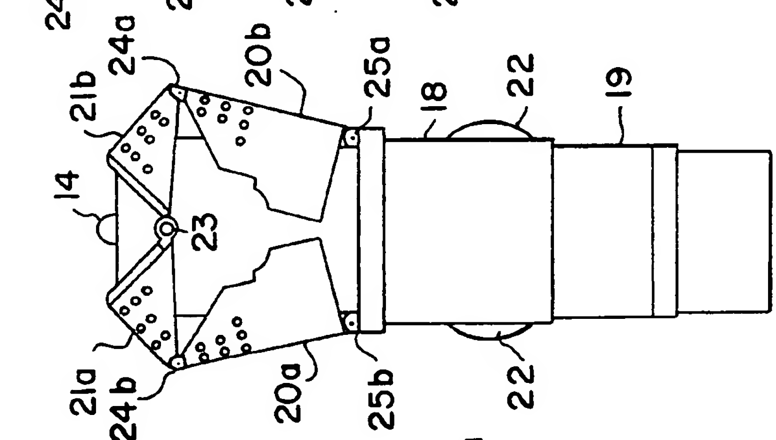

FIG.4c

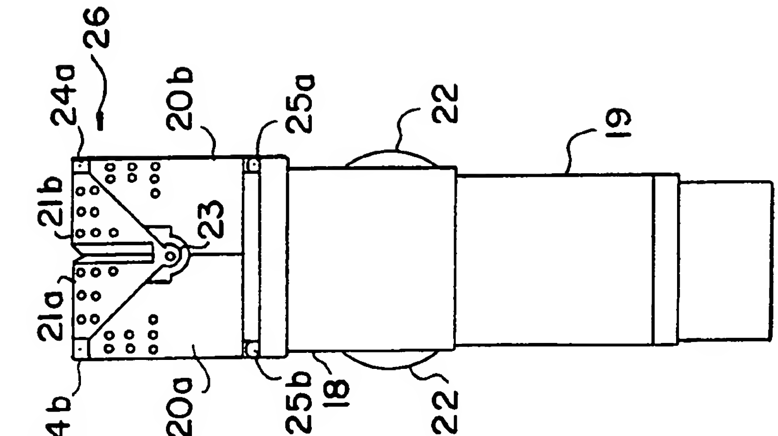

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FIG. 5

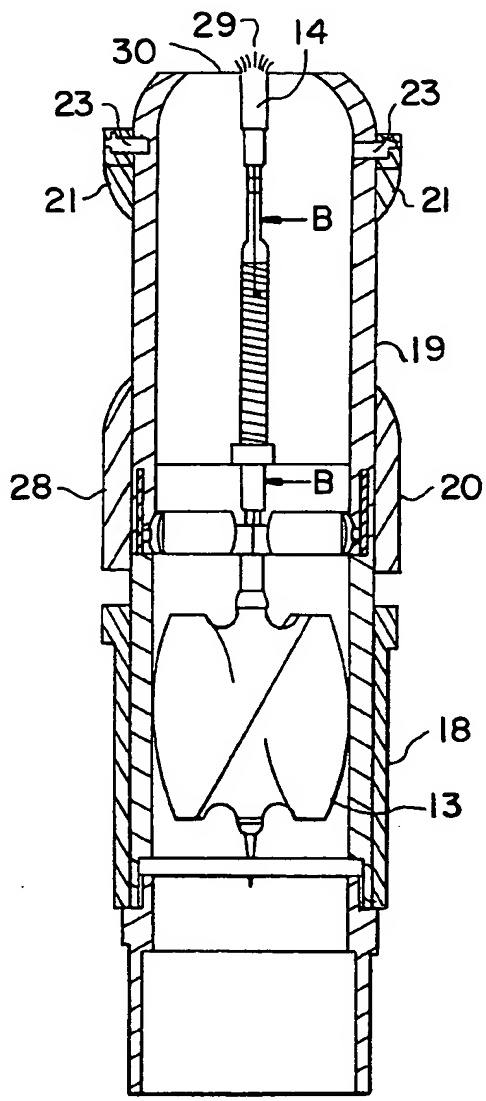

FIG.6

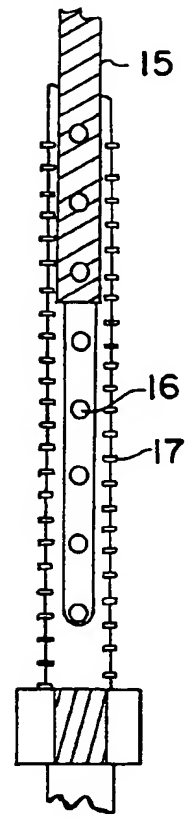

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FIG. 7

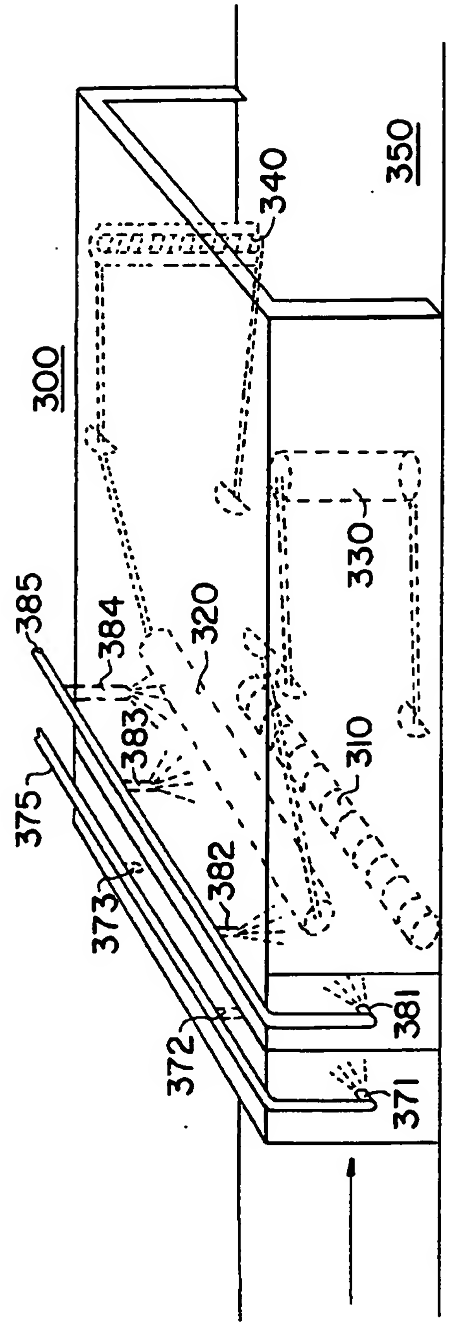


FIG. 9

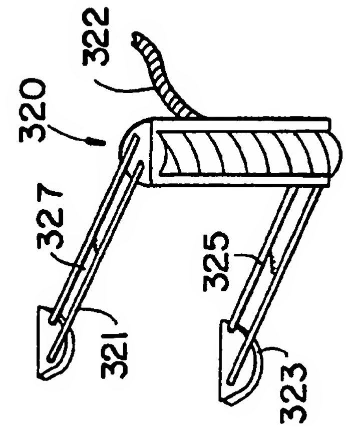


FIG. 8

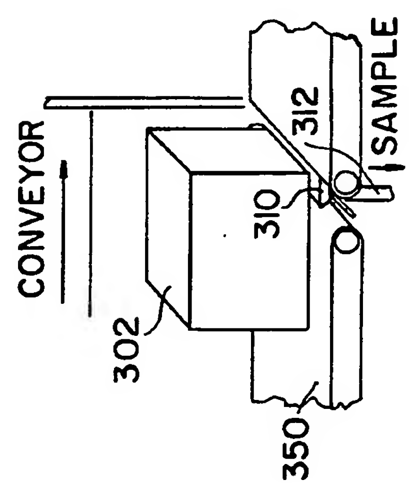


FIG. 12

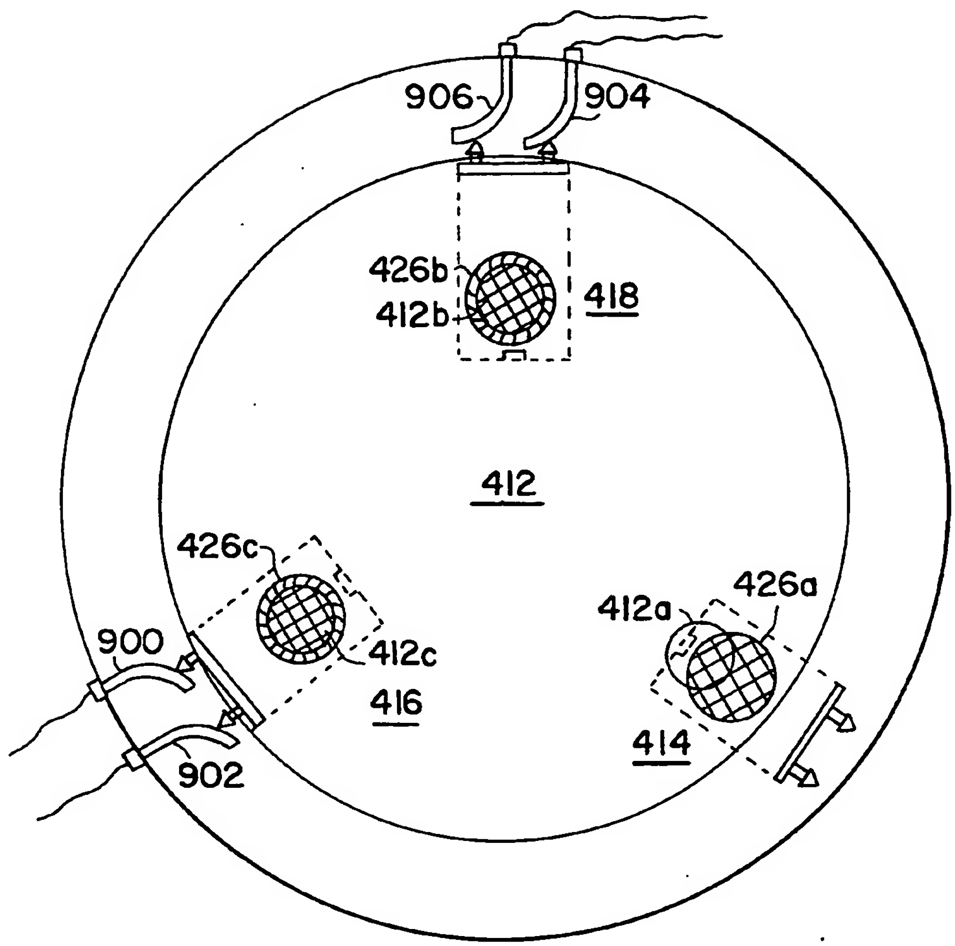
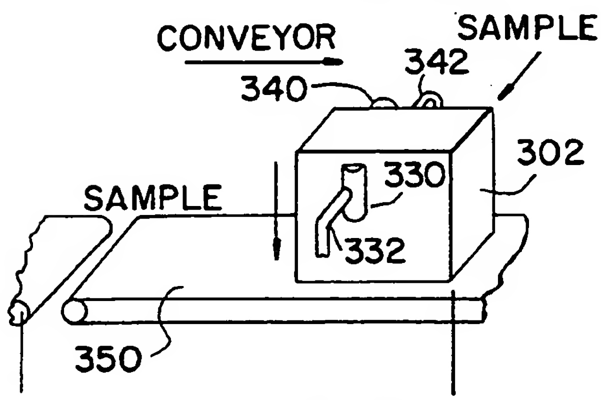


FIG. 10



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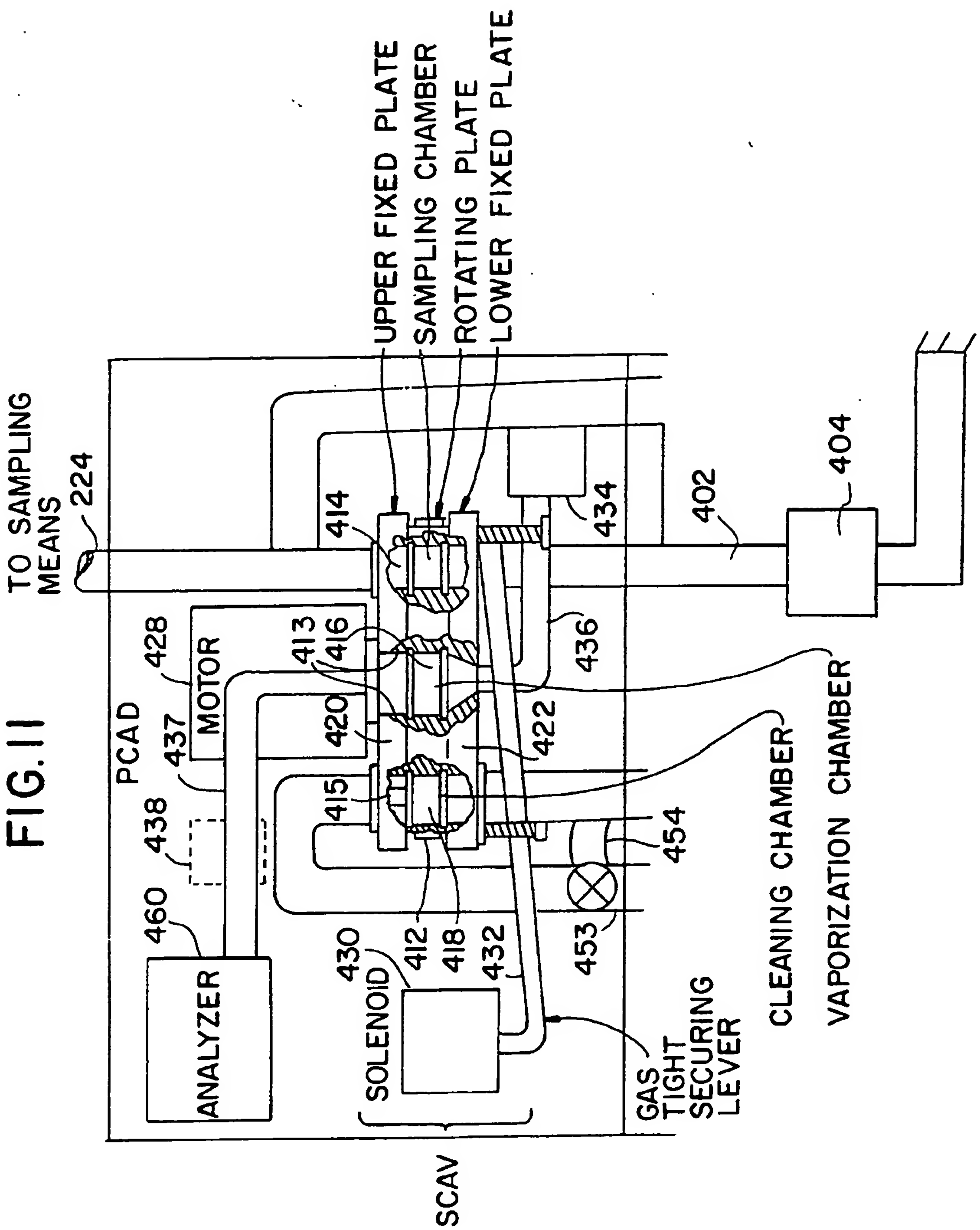

FIG.11

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FIG.13

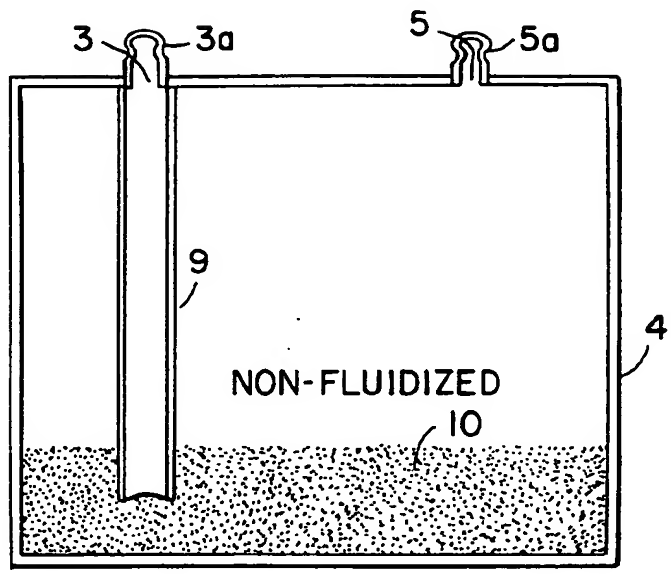

FIG.14

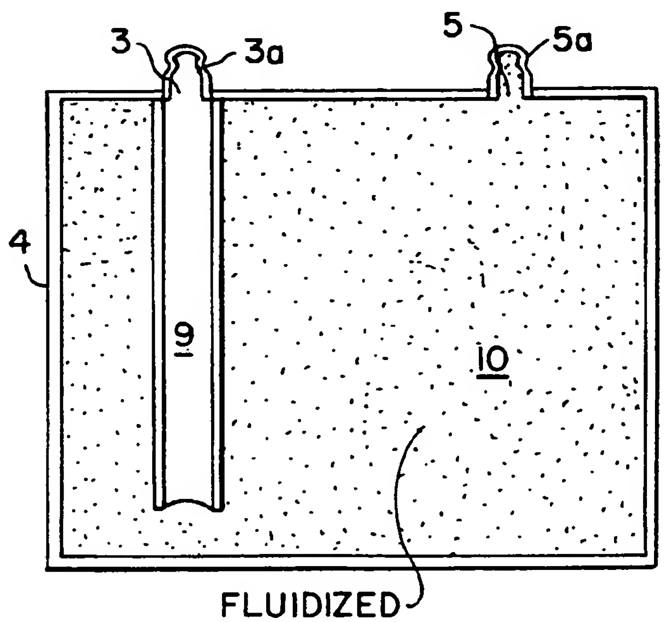

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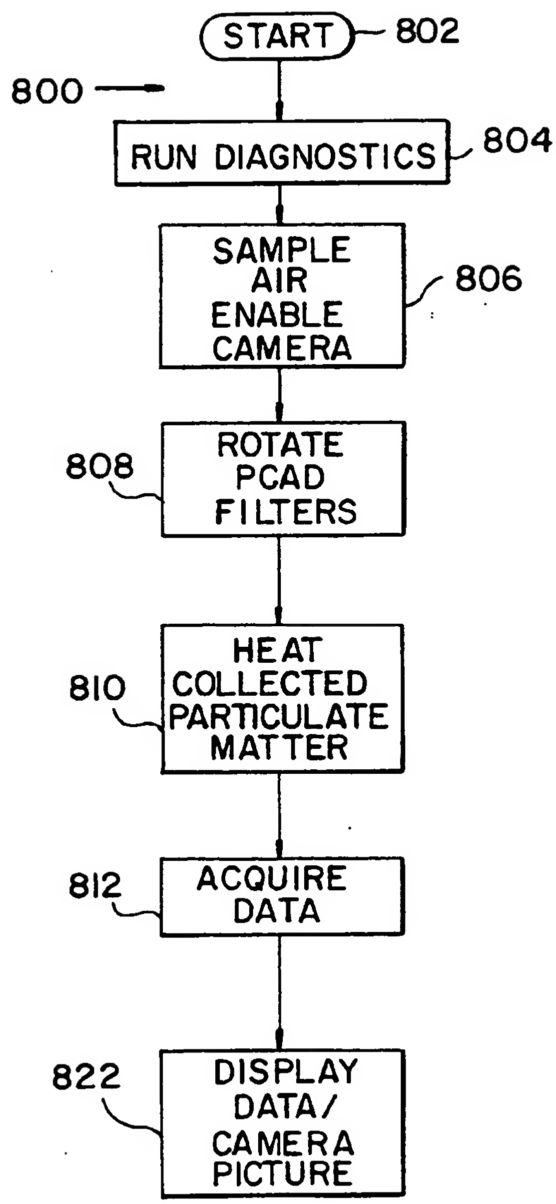
FIG. 15



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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US93/04374

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :G01N 33/22; G08B 21/00; A47L 9/04
US CL :73/23.2, 864.33; 15/320, 339, 387, 415.1; 340/ 568, 632
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : Please See Extra Sheet.

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Please See Extra Sheet.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, A, 3,748,905 (Zahlava) 31 July 1973, entire document.	1-25
A	US, A, 4,837,888 (Maier) 13 June 1989, entire document.	24
A	US, A, 4,909,090 (McGown et al.) 20 March 1990, entire document.	1-25
A	US, A, 5,083,019 (Spangler) 21 January 1992, entire document.	1-24
Y	US, A, 5,109,691 (Corrigan et al.) 05 May 1992, col. 10, line 31-col. 18 line 7.	1-23, 25

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

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Date of the actual completion of the international search
07 November 1993

Date of mailing of the international search report
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US93/04374

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, A, 5,162,652 (Cohen et al.) 10 November 1992, entire document.	1-23, 25
A,E	US, A, 5,251,496 (Platek) 12 October 1993, entire document.	1-23, 25

B. FIELDS SEARCHED
Minimum documentation searched
Classification System: U.S.

73/23.2, 23.35, 23.37, 23.41, 31.01, 31.07, 864, 863.21, 863.12, 864.34, 864.81, 864.33, 864.71; 340/ 568, 627, 632, 540; 15/302, 320, 339, 344, 345, 373, 383, 387, 393, 415.1; 134/ 7, 10, 21, 32, 93, 113, 198

B. FIELDS SEARCHED
Electronic data bases consulted (Name of data base and where practicable terms used):

APS
search terms: (detect? or locat?) (3a) explosive?, dust, vacuum, (vacuum (p) dust), dust, vacuum, partic?, plastic (3a) explosive?, vacuum